8.2.13 ENVIRONMENTAL JUSTICE

As discussed in Chapter 4, Section 4.1.13, the environmental justice analysis brings together the results of all resource and feature analyses to determine (1) if an activity would have substantial environmental impacts and (2) if those substantial impacts would have disproportionately high and adverse human health or environmental effects on minority or low-income populations. DOE determined that cumulative impacts from Inventory Module 1 or 2 along with those expected from other Federal, non-Federal, and private actions would not produce cumulative adverse impacts to any surrounding populations, which would include minority and low-income populations. Evaluation of subsistence lifestyles and cultural values has confirmed that these factors would not change the conclusion that the absence of high and adverse impacts for the general population means there would be no disproportionately high and adverse impacts on minority or low-income communities. No substantial impacts were identified; therefore, cumulative impacts from Inventory Module 1 or 2 and other Federal, non-Federal, and private actions would not cause environmental justice concerns.

DOE recognizes that Native American people living in areas near Yucca Mountain have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action, and that the implementation of the Proposed Action would continue restrictions on access to the site. Chapter 4, Section 4.1.3.4, discusses these views and beliefs.

8.3 Cumulative Long-Term Impacts in the Proposed Yucca Mountain Repository Vicinity

This section describes results from the long-term cumulative impact analysis that DOE conducted for Inventory Modules 1 and 2 (Section 8.3.1) and for past, present, and reasonably foreseeable future actions at the Nevada Test Site, and past actions at the Beatty low-level radioactive waste site (Section 8.3.2).

8.3.1 INVENTORY MODULE 1 OR 2 IMPACTS

The analysis of long-term performance for Inventory Modules 1 and 2 used the same methodology described in Chapter 5 and Appendix I for the Proposed Action to estimate potential human health impacts from radioactive and chemically toxic material releases through waterborne and airborne pathways. Section 8.3.1.1 presents the radioactive and chemically toxic material source terms for Inventory Modules 1 and 2, and Sections 8.3.1.2 and 8.3.1.3 present the results of the analysis for Inventory Modules 1 and 2, respectively.

In addition to long-term human health impacts from radioactive and chemically toxic material releases, the other potential long-term impact identified following repository closure involve biological resources. Though the surface area affected by heat rise would be larger for Inventory Module 1 or 2, the amount of heat per unit area would be constant for a given repository operating mode (lower- or higher-temperature), and, therefore, the small ground surface temperature increase would be the same. Thus, long-term biological effects of Module 1 or 2 from heat generated by waste packages that would potentially raise ground surface temperatures would be the same as those described in Chapter 5, Section 5.9 for the Proposed Action.

8.3.1.1 Radioactive and Chemically Toxic Material Source Terms for Inventory Modules 1 and 2

For calculations of long-term performance impacts, the radioactive material inventory of individual waste packages for commercial spent nuclear fuel, high-level radioactive waste, and DOE spent nuclear fuel under Inventory Modules 1 and 2 would be identical to the radioactive material inventory under the

Proposed Action for the same waste categories. Inventory Module 2 includes an additional waste category for Greater-Than-Class-C and Special-Performance-Assessment-Required wastes. This category includes a different category of waste package with its own radioactive material inventory. This waste was simulated with 601 idealized waste packages. The inventory used for each modeled waste package is an averaged radioactive material inventory of each waste category (commercial spent nuclear fuel, DOE spent nuclear fuel, high-level radioactive waste, and Greater-Than-Class-C and Special-Performance-Assessment-Required wastes). More waste packages would be used for Inventory Modules 1 and 2 than for the Proposed Action to accommodate the expanded inventories. Table 8-42 lists the number of waste packages used in the analysis of long-term performance calculations for the Proposed Action and Modules 1 and 2.

Table 8-42. Number of idealized waste packages used in analysis of long-term performance calculations.[a]

Modeled inventory	Commercial SNF[b]	Codisposal (DOE SNF and HLW[c])	GTCC and SPAR[d]	Total
Proposed Action	7,860	3,910	0	11,770
Inventory Module 1	11,754	4,877	0	16,631
Inventory Module 2	11,754	4,877	601	17,232

a. The idealized waste packages in the simulation (model) are based on the inventory abstraction in Appendix I, Section I.3. While the total inventory is represented by the material in the idealized waste packages, the actual number of waste packages emplaced in the proposed repository would be different.
b. SNF = spent nuclear fuel.
c. HLW = high-level radioactive waste.
d. GTCC = Greater-Than-Class-C; SPAR = Special-Performance-Assessment-Required.

IDEALIZED WASTE PACKAGES

The number of waste packages used in the performance assessment simulations do not exactly match the number of actual waste packages specified in DIRS 150558-CRWMS M&O (2000, Section 6.2).

The TSPA model uses two types of *idealized waste packages* (commercial spent nuclear fuel package and codisposal package), representing the averaged inventory of all the actual waste packages used for a particular waste category.

While the number of idealized waste packages varies from the number of actual waste packages in DIRS 150558-CRWMS M&O (2000, Section 6.2), the total radionuclide inventory represented by all of the idealized waste packages collectively is representative of the total inventory, for the radionuclides analyzed, given in Appendix A of this EIS for the purposes of analysis and long-term performance. *The abstracted inventory is designed to be representative for purposes of analysis of long-term performance and cannot necessarily be used for any other analysis, nor can it be directly compared to any other abstracted inventory used for other analyses in this EIS.*

As listed in Table 8-42, Inventory Module 2 differs from Inventory Module 1 only by the addition of 601 Greater-than-Class-C and Special-Performance-Assessment-Required idealized waste packages. Table 8-43 lists the inventory of the Greater-than-Class-C and Special-Performance-Assessment-Required waste packages under Inventory Module 2.

A screening analysis documented in Appendix I, Section I.6.1, showed that the only chemical materials of concern for the 10,000-year analysis period were those that would be released as the external waste package Alloy-22 layer and the waste package support pallet materials corroded. This is because most waste packages would be intact for more than 10,000 years after closure (the results of the analysis of

Table 8-43. Abstracted inventory (grams) of radionuclides passing the screening analysis in each idealized waste package for Greater-Than-Class-C and Special-Performance-Assessment-Required wastes under Inventory Module 2.[a]

Isotope	Inventory
Actinium-227	0
Americium-241	40
Americium-243	0.00151
Carbon-14	28.9
Cesium-137	771
Iodine-129	0.000705
Nickel-63	0
Neptunium-237	0
Protactinium-231	0
Lead-210	0
Plutnium-238	1.56
Plutonium-239	2,860
Plutonium-240	0.0123
Plutonium-241	0.0207
Plutonium-242	0.00614
Radium-226	0.0504
Radium-228	0
Strontium-90	0.82
Technetium-99	568
Thorium-229	0
Thorium-230	0
Thorium-231	0
Uranium-232	0.00000287
Uranium-233	0.00419
Uranium-234	0
Uranium-235	0
Uranium-236	0

a. The idealized waste packages in the simulation (model) are based on the inventory abstraction in Appendix I, Section I.3. While the total inventory is represented by the material in idealized waste packages, the actual number of waste packages emplaced in the proposed repository would be different.

long-term performance for radionuclides described in Appendix I, Section I.5, show that, at most, only three waste packages would be breached before 10,000 years, due to improper heat treatment, under the Proposed Action). Therefore, accounting for the quantities of materials in the engineered barrier system, but not in the waste packages, and accounting for toxicity to humans, the only chemical materials of concern would be chromium, nickel, molybdenum, and vanadium. The inventories of these chemical materials in the engineered barrier system for the Proposed Action and Inventory Modules 1 and 2 are listed in Table 8-44. These are essentially the only inventories available for mobilization and transport within 10,000 years after closure; the inventories of chemical materials in the waste packages would not begin to degrade until waste package failure. Further information on the inventory of chemical materials of concern is provided in Appendix I, Section I.3.

The only radionuclide that would have a relatively large inventory and a potential for gas transport is carbon-14. Iodine-129 can exist in a gas phase, but it is highly soluble and, therefore, would be likely to dissolve in groundwater rather than migrate as a gas. Radon-222 is a gas, but would decay to a solid isotope before escaping from the repository region (see Appendix I, Section I.7.3). After the carbon-14 escaped from the waste package, it could flow through the fractured and porous rock in the form of carbon dioxide. About 2 percent of the carbon-14 in commercial spent nuclear fuel is in gas in the space (or gap) between the fuel and the cladding around the fuel (DIRS 103446-Oversby 1987, p. 92). There are 1.37 grams of carbon-14 in an abstracted commercial spent nuclear fuel waste package (see Appendix I, Table I-5). This represents 6.11 curies per waste package. Since 2 percent of the total is gaseous, the gaseous inventory consists of 0.122 curie of carbon-14 per commercial spent nuclear fuel waste package. There would be additional carbon-14 activity associated with Inventory Module 2, in relation to Module 1, resulting from neutron irradiation of the core shroud metal. The carbon-14 would be unlikely to be present as gaseous carbon dioxide that could be released to the environment and is therefore not included in Table 8-45.

Table 8-44. Total quantities of waterborne chemicals of concern in the engineered barrier system under the Proposed Action and Inventory Modules 1 and 2 (kilograms).[a,b]

Modeled inventory	Chromium	Molybdenum	Nickel	Vanadium
Proposed Action	23,735,000	17,307,000	60,797,000	377,600
Inventory Module 1	34,695,000	25,301,000	88,879,000	552,000
Inventory Module 2	34,951,000	25,490,000	89,545,000	556,000

a. To convert kilograms to pounds, multiply by 2.2046.
b. See screening analysis in Appendix I, Section I.3.2.

Table 8-45. Total **gaseous** carbon-14 in the repository from commercial spent nuclear fuel for the Proposed Action and Inventory Modules 1 and 2 (curies).

Modeled inventory	Quantity[a]
Proposed Action	959
Inventory Module 1	1,430
Inventory Module 2	1,430

a. Based on 0.122 curies of carbon-14 per commercial spent nuclear fuel waste package.

8.3.1.2 Impacts for Inventory Module 1

The human-health impacts from Inventory Module 1 for radioactive materials and chemically toxic materials are discussed in this section.

8.3.1.2.1 *Waterborne Radioactive Material Impacts*

The DOE used the modeling methods described for the Proposed Action in Chapter 5 (and in greater detail in Appendix I) to calculate the impacts both for an individual and the local population resulting from groundwater releases of radioactive material for 10,000 years and 1 million years following repository closure for Inventory Module 1.

8.3.1.2.1.1 Higher-Temperature Operating Mode. Table 8-46 lists the estimated impacts for an individual for the higher-temperature operating mode under the Proposed Action and Inventory Module 1. The peak annual individual dose for the first 10,000 years shows slightly higher values for the mean and 95th percentile of the Proposed Action than for Module 1. Because Module 1 has a higher inventory, this would seem like an incorrect trend. However, note that in the first 10,000 years releases are dominated by at most about 3 waste package failures due to a manufacturing defect (improper heat treatment). Thus, the release is essentially insensitive to inventory and the differences in Table 8-46 between the Proposed Action and Module 1 are merely the result of slightly different statistical outcomes in the 300 simulations.

Table 8-46. Impacts for an individual from groundwater releases of radionuclides during 10,000 years after repository closure for the higher-temperature repository operating mode under the Proposed Action and Inventory Module 1.

		Mean			95th-percentile		
Modeled inventory	Individual	Peak annual individual dose (millirem)	Time of peak (years)	Probability of a LCF[a]	Peak annual individual dose (millirem)	Time of peak (years)	Probability of a LCF[a]
Proposed Action	At RMEI location[b]	0.00002[c]	4,900	6×10^{-10}	0.0001[d]	4,900	4×10^{-9}
	At 30 kilometers[e]	~0[f]	NC[g]	~0	~0[f]	NC[g]	~0
	At discharge location[h]	~0[f]	NC[g]	~0	~0[f]	NC[g]	~0
Inventory Module 1	At RMEI location[b]	0.00003[c]	4,900	1×10^{-9}	0.002[d]	4,100	6×10^{-9}
	At 30 kilometers[d]	~0[f]	NC[g]	~0	~0[f]	NC[g]	~0
	At discharge location[h]	~0[f]	NC[g]	~0	~0[f]	NC[g]	~0

a. LCF = latent cancer fatality; incremental lifetime (70 years) risk of contracting a fatal cancer, assuming a risk of 0.0005 latent cancer fatality per rem for members of the public (DIRS 101856-NCRP 1993, p. 31).
b. The RMEI location, defined in 40 CFR Part 197, is where the predominant groundwater flow path crosses the boundary of the controlled area and is approximately 18 kilometers (11 miles) downgradient from the repository. The maximum allowable peak of the mean annual individual dose for 10,000 years at this distance is 15 millirem.
c. Based on 300 simulations of total system performance, using random samples of uncertain parameters.
d. Represents a value for which 285 out of the 300 simulations yielded a smaller value.
e. To convert kilometers to miles, multiply by 0.62137.
f. Values would be lower than the small values computed for the RMEI location.
g. NC = not calculated (peak time would be greater than time given for the RMEI location).
h. 60 kilometers (37 miles) at Franklin Lake Playa.

Table 8-47 lists the impacts to the population during the first 10,000 years after repository closure for both the Proposed Action and Inventory Module 1 for the higher-temperature operating mode. These impacts were calculated on the same population basis used for the Proposed Action calculations presented in Chapter 5, that is a population size was based on the projected population numbers for 2035 in Figure 3-25 in Chapter 3. For these calculations, the analysis assumed that no contaminated groundwater

Table 8-47. Population impacts from groundwater releases of radionuclides during 10,000 years after repository closure for the higher-temperature repository operating mode under the Proposed Action and Inventory Module 1.[a]

		Mean		95th-percentile	
Modeled inventory	Case	Population dose (person-rem)	Population LCFs[b]	Population dose (person-rem)	Population LCFs[b]
Proposed Action	Peak 70-year lifetime	0.006	0.000003	0.04	0.00002
	Integrated over 10,000 years	0.5	0.0002	0.6	0.0003
Inventory Module 1	Peak 70-year lifetime	0.01	0.000005	0.06	0.00003
	Integrated over 10,000 years	0.7	0.0003	0.8	0.0004

a. Based on 300 simulations of total system performance for each location, using random samples of uncertain parameters.
b. LCF = latent cancer fatality; expected number of cancer fatalities for populations, assuming a risk of 0.0005 latent cancer fatality per rem for members of the public (DIRS 101856-NCRP 1993, p. 31).

would reach populations in any regions to the north of Yucca Mountain. Therefore, populations in the sectors north of the due east and due west sectors were not considered to be exposed.

- 47 people would be exposed at the Reasonably Maximally Exposed Individual (RMEI) location [approximately 18 kilometers (11 miles)] downgradient from the repository [includes sectors from 12 to 28 kilometers (7 to 27 miles)].
- 4,200 people would be exposed at about 30 kilometers (19 miles) downgradient from the potential repository [includes sectors from 28 to 44 kilometers (17 to 27 miles)].
- 69,500 people would be exposed at the discharge location, about 60 kilometers (37 miles) downgradient of the potential repository [includes sectors from 44 to 80 kilometers (27 to 50 miles)].

Thus, approximately 74,000 people would be exposed to contaminated groundwater. This stylized population dose analysis assumed that people would continue to live in the locations being used at present. This assumption is consistent with the recommendation made by the National Academy of Sciences (DIRS 100018-National Research Council 1995, all) because it is impossible to make accurate predictions of future lifestyles and residence locations far into the future.

The population impacts would be greater than the impacts for the Proposed Action under the higher-temperature operating mode. For example, the population dose in the 70-year period of maximum impacts would be about 25 percent greater for Module 1 than for the Proposed Action at the mean level and the same 70-year period.

The values in Table 8-47 include a scaling factor for water use. The performance assessment transport model calculated the annual individual dose assuming the radionuclides dissolved in water that flowed through the unsaturated zone of Yucca Mountain would mix in an average of 2.4 million cubic meters (1,940 acre-feet) (DIRS 155950-BSC 2001, p. 13-42) per year in the saturated zone aquifer. This compares to an annual water use in the Amargosa Valley of about 17.1 million cubic meters (13,900 acre-feet) (DIRS 155950-BSC 2001, p. 13-42). The analysis diluted the concentration of the nuclides in the 2.4 million cubic meters of water throughout the 17.1 million cubic meters of water prior to calculating the population dose.

Table 8-48 lists the peak annual individual dose and time of peak for 1 million years after repository closure for both Inventory Module 1 and the Proposed Action for the higher-temperature operating mode. The impacts would follow the same pattern as those for the first 10,000 years after repository closure listed in Table 8-47, with the impacts for Module 1 about 60 percent greater than those for the Proposed Action.

Table 8-48. Impacts to an individual from groundwater releases of radionuclides for 1 million years after repository closure for the higher-temperature repository operating mode under the Proposed Action and Inventory Module 1.

		Mean		95th-Percentile	
Modeled inventory	Individual	Peak annual individual dose (millirem)	Time of peak (years)	Peak annual individual dose (millirem)	Time of peak (years)
Proposed Action	At RMEI location[a]	150[b]	480,000	620[c]	410,000
	At 30 kilometers[d]	100[e]	NC[f]	420[e]	NC[f]
	At discharge location[g]	59[e]	NC[f]	240[e]	NC[f]
Inventory Module 1	At RMEI location[a]	240[b]	480,000	980[c]	480,000
	At 30 kilometers[d]	160[e]	NC[f]	660[e]	NC[f]
	At discharge location[g]	90[e]	NC[f]	450[e]	NC[f]

a. The RMEI location, defined in 40 CFR Part 197, is where the predominant groundwater flow path crosses the boundary of the controlled area and is approximately 18 kilometers (11 miles) downgradient from the repository.
b. Based on 300 simulations of total system performance for each location, using random samples of uncertain parameters.
c. Represents a value for which 285 out of the 300 simulations yielded a smaller value.
d. To convert kilometers to miles, multiply by 0.62137.
e. Estimated using scale factors as described in Chapter 5, Section 5.4.1.
f. NC = not calculated (peak time would be greater than time given for the RMEI location).
g. 60 kilometers (37 miles) at Franklin Lake Playa.

WHY ARE THE MEAN IMPACTS SOMETIMES HIGHER THAN THE 95TH-PERCENTILE IMPACTS?

The *mean* impact is the arithmetic average of the 300 impact results from simulations of total-system performance. The mean is not the same as the 50th-percentile value (the 50th-percentile value is called the *median*) if the distribution is *skewed*.

The performance results reported in this EIS come from highly skewed distributions. In this context, *skewed* indicates that there are a few impact estimates that are much larger than the rest of the impacts. When a large value is added to a group of small values, the large value dominates the calculation of the mean. The simulations reported in this EIS have mean impacts that are occasionally above the 90th-percentile and occasionally above the 95th percentile.

With respect to groundwater protection standards set forth in 40 CFR Part 197.30, both the mean and the 95th percentile estimated levels during the 10,000-year regulatory period are hundreds of thousands of times less than the regulatory limits (see Table 8-49) for both the Proposed Action and Inventory Module 1.

8.3.1.2.1.2 Lower-Temperature Operating Mode. Impacts were not calculated for the lower-temperature operating mode under Inventory Module 1 or 2 because of the lack of differentiation between higher-temperature and lower-temperature operating modes under the Proposed Action (see Chapter 5). Comparison of the mean individual dose history at the RMEI location for the lower- and higher-temperature operating modes is shown in Figure 8-4. For the Proposed Action, the individual dose for the lower-temperature operating mode at a given location would be about the same as that for the higher-temperature operating mode, with the long-term peak slightly greater for the higher-temperature operating mode. Calculations for Inventory Module 1 produce a similar response. Given the similarity of impacts, and that the lower-temperature operating mode impacts are generally bounded by the higher-temperature operating mode impacts, it was deemed unnecessary to perform detailed simulations for the lower-temperature operating mode under Inventory Module 1. The results would be similar to, but less than, those for the higher-temperature operating mode under Inventory Module 1, as reported in Section 8.3.1.2.1.1.

Table 8-49. Comparison of nominal scenario long-term consequences at the RMEI location[a] to groundwater protection standards during 10,000 years following repository closure for the higher-temperature repository operating mode under the Proposed Action and Inventory Module 1.

Modeled inventory	Radionuclide or type of radiation emitted	EPA Limit[b]	Mean peak[c]	95th-percentile peak[d]
Proposed Action	Combined radium-226 and radium-228,[e] picocuries per year	5	1.0 (1×10^{-11})[f]	1.0 (2×10^{-11})
	Gross alpha activity (including radium-226 but excluding radon and uranium),[e] picocuries per year	15	0.4 (2×10^{-8})	0.4 (1×10^{-8})
	Combined beta and photon emitting radionuclides,[g] millirem per year to the whole body or any organ, based on drinking 2 liters of water per day from the representative volume	4	2×10^{-5}	1×10^{-4}
Inventory Module 1	Combined radium-226 and radium-228,[e] picocuries per year	5	1.0 (3×10^{-10})	1.0 (3×10^{-11})
	Gross alpha activity (including radium-226 but excluding radon and uranium),[e] picocuries per year	15	0.4 (3×10^{-8})	0.4 (4×10^{-8})
	Combined beta and photon emitting radionuclides,[g] millirem per year to the whole body or any organ, based on drinking 2 liters of water per day from the representative volume	4	3×10^{-5}	2×10^{-4}

a. The RMEI location, defined in 40 CFR Part 197, is where the predominant groundwater flow path crosses the boundary of the controlled area and is located approximately 18 kilometers (11 miles) downgradient from the repository.
b. Environmental Protection Agency limits set forth in 40 CFR Part 197.30.
c. Based on 300 simulations of total system performance, each using random samples of uncertain parameters.
d. Represents a value for which 285 out of the 300 simulations yielded a smaller value.
e. Includes natural background radiation.
f. Value in parentheses is the incremental increase over background radiation that would be attributable to the potential repository.
g. This represents a bounding (overestimate) of the maximum dose to any organ because the different radionuclides would affect different organs preferentially.

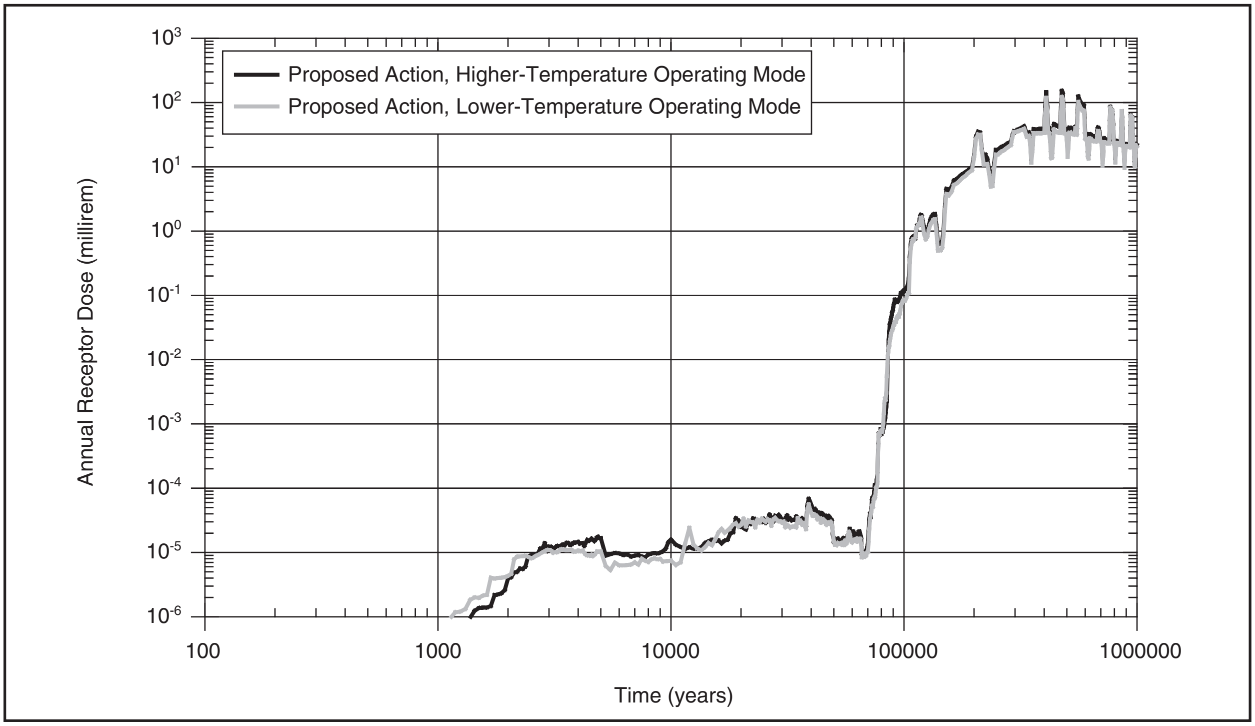

Figure 8-4. Comparison of mean annual individual dose (based on 300 simulations of total system performance, each using random samples of uncertain parameters) at the RMEI location for the higher- and lower-temperature operating modes. (Note use of logarithmic scale for both axes.)

8.3.1.2.2 *Waterborne Chemically Toxic Material Impacts*

A number of nonradioactive materials that DOE would place in the repository are hazardous to human health at high concentrations in water. This section examines the consequences to individuals in the Amargosa Desert from releases of these nonradioactive materials under Inventory Module 1.

The inventory of chemically toxic materials that would be emplaced in the repository under the Proposed Action is identified by element in Appendix I, Section I.3. Based on this inventory, a screening analysis (described in Appendix I, Section I.6.1) identified which of the chemically toxic materials might pose a risk to human health. Only chromium, molybdenum, nickel, and vanadium were identified as potentially posing such a risk, and these elements were further evaluated in a bounding consequence analysis, as described in Appendix I, Section I.6.2. The analysis was performed under the conservative assumption that all chromium dissolves in hexavalent form. The results of the bounding analysis are summarized for both the Proposed Action and Inventory Module 1 in Table 8-50. In some cases a Maximum Containment Level or Maximum Contaminant Level Goal was available for comparison to the calculated concentration. In other cases, only an Oral Reference Dose was available. The Oral Reference Dose can be compared to intake that would result for a 70-kilogram (154-pound) person drinking 2 liters (0.53 gallon) of water per day. More detail on these comparative measures can be found in Chapter 5, Section 5.6, and Appendix I, Section I.6.2.5.

Table 8-50. Peak concentration of waterborne chemical materials released during 10,000 years after closure estimated using bounding calculations for the Proposed Action and Inventory Module.

Modeled inventory	Material	Estimated concentration in well water (milligram per liter)	Maximum Contaminant Level Goal (milligram per liter)	Estimated intake rate for a 70-kilogram person (milligram per kilogram per day)	Oral Reference Dose (milligram per kilogram per day)
Proposed Action	Chromium (VI)	0.01	0.1[a]	0.0004	0.005[b]
	Molybdenum	0.009	NA[c]	0.0003	0.005[d]
	Nickel	0.04	NA	0.001	0.02[e]
	Vanadium	0.0002	NA	0.000006	0.007[f]
Inventory Module 1	Chromium (VI)	0.02	0.1[a]	0.0006	0.005[b]
	Molybdenum	0.01	NA	0.0004	0.005[d]
	Nickel	0.05	NA	0.002	0.02[e]
	Vanadium	0.0003	NA	0.000009	0.007[f]

a. 40 CFR 191.51.
b. DIRS 148224-EPA (1999, all).
c. NA = not available.
d. DIRS 148228-EPA (1999, all).
e. DIRS 148229-EPA (1999, all).
f. DIRS 103705-EPA (1997, all).

Because the bounding concentration of chromium, molybdenum, nickel, and vanadium in well water is calculated to be below the Maximum Contaminant Level Goal or yield intakes well below the Oral Reference Dose for Inventory Module 1, there is no further need to refine the calculation to account for physical processes that would limit mobilization of this material or delay or dilute it during transport in the geosphere.

8.3.1.2.3 *Atmospheric Radioactive Material Impacts*

Using the analysis methods described in Chapter 5, Section 5.5, DOE estimated the impacts of carbon-14 releases to the atmosphere within 10,000 years past closure for Inventory Module 1. As explained in Appendix I, Section I.7.1, the maximum release rate to the ground surface for this period is the same for both Inventory Modules 1 and 2 as for the Proposed Action. Therefore, there would be no incremental atmospheric radioactive material impacts for Inventory Module 1 for the Proposed Action.

8.3.1.3 INCREMENTAL IMPACTS FOR INVENTORY MODULE 2

DOE addressed the long-term consequences from Inventory Module 2 by analyzing the effects of disposing waste packages containing Greater-Than-Class-C and Special-Performance-Assessment-Required wastes in addition to the material in Inventory Module 1. Table 8-43 lists the average inventory of the additional waste packages containing Greater-Than-Class-C and Special-Performance-Assessment-Required wastes. The following sections discuss these impacts in terms of waterborne radioactive releases, chemically toxic materials waterborne release, and atmospheric radioactive material releases.

8.3.1.3.1 *Waterborne Radioactive Material Impacts*

The addition of Greater-Than-Class-C and Special-Performance-Assessment-Required wastes is the only difference between Inventory Modules 1 and 2. Inventory Module 2 was modeled as an incremental inventory; specifying only the Greater-Than-Class-C and Special-Performance- Assessment-Required waste as the radionuclide inventory. The results of the incremental inventory simulations constitute the additional impacts of Inventory Module 2 over those of Module 1. In addition, they represent the dose attributable solely to the Greater-Than-Class-C and Special- Performance-Assessment-Required waste.

Table 8-51 lists the incremental consequences for an individual from the Greater-Than-Class-C and Special-Performance-Assessment-Required wastes in Inventory Module 2 during 10,000 years and 1 million years following repository closure. Peak impacts from waterborne radioactive materials for Module 2 would be less than 1 percent higher for 1,000,000 years after repository closure. For the first 10,000 years following the repository closure, the Module 2 impact would remain very small (mean annual individual dose of 0.0007 millirem, compared to the Environmental Protection Agency standard of 15 millirem for this period as defined in 40 CFR Part 197).

Table 8-51. Incremental increase (millirem) in mean peak individual annual dose at the RMEI location[a] under Inventory Module 2 over the mean peak individual annual dose under Inventory Module 1 during 10,000 and 1 million years after repository closure.

Postclosure period	Incremental Increase[b]
10,000 years	0.0007
1,000,000 years	0.3

a. The RMEI location, defined in 40 CFR Part 197, is where the predominant groundwater flow path crosses the boundary of the controlled area and is approximately 18 kilometers (11 miles) downgradient from the repository.

b. Based on 300 simulations each for Inventory Modules 1 and 2 using random samples of uncertain parameters.

8.3.1.3.2 *Waterborne Chemically Toxic Material Impacts*

A number of nonradioactive materials that DOE would place in the repository are hazardous to human health at high concentrations in water. This section examines the consequences to individuals in the Amargosa Desert from releases of these nonradioactive materials under Inventory Module 2.

The inventory of chemically toxic materials that would be emplaced in the repository under the Proposed Action is identified by element in Appendix I, Section I.3. Based on this inventory, a screening analysis (described in Appendix I, Section I.6.1.) identified which of the chemically toxic materials could pose a risk to human health. Only chromium, molybdenum, nickel, and vanadium were identified as posing such a risk, and these elements were further evaluated in a bounding consequence analysis, as described in Appendix I, Section I.6.2. The results of the bounding analysis are summarized for both the Proposed Action and Inventory Module 2 in Table 8-52. In some cases a Maximum Contaminant Level Goal was available for comparison to the calculated concentration. In other cases, only an Oral Reference Dose was available. The Oral Reference Dose can be compared to the intake that would result for a 70-kilogram (154-pound) person drinking 2 liters (0.53 gallon) of water per day. More detail on these comparative measures can be found in Chapter 5, Section 5.6, and Appendix I, Section I.6.2.5.

Table 8-52. Peak concentration of waterborne chemical materials released during 10,000 years after closure estimated using bounding calculations for the Proposed Action and Inventory Module 2.

Modeled inventory	Material	Estimated concentration in well water (milligram per liter[a])	Maximum Contaminant Level Goal (milligram per liter)	Estimated intake rate for a 70-kilogram person (milligram per kilogram per day)	Oral Reference Dose (milligram per kilogram per day)
Proposed Action	Chromium (VI)	0.01	0.1[a]	0.0004	0.005[b]
	Molybdenum	0.009	NA[c]	0.0003	0.005[d]
	Nickel	0.04	NA	0.001	0.02[e]
	Vanadium	0.0002	NA	0.000006	0.007[f]
Inventory Module 2	Chromium (VI)	0.02	0.1	0.0006	0.005[b]
	Molybdenum	0.01	NA	0.0004	0.005[d]
	Nickel	0.06	NA	0.002	0.02[e]
	Vanadium	0.0003	NA	0.00001	0.007[f]

a. 40 CFR 191.51.
b. DIRS 148224-EPA (1999, all).
c. NA = not available.
d. DIRS 148228-EPA (1999, all).
e. DIRS 148229-EPA (1999, all).
f. DIRS 103705-EPA (1997, all).

Because the bounding concentration of chromium, molybdenum, nickel, and vanadium in well water is calculated to be below the Maximum Containment Level Goal or yield intakes well below the Oral Reference Dose for Inventory Module 2, there is no further need to refine the calculation to account for physical processes that would limit mobilization of this material or delay or dilute it during transport in the geosphere.

The incremental (that is, the increase in) consequences for an individual from the Greater-Than-Class-C and Special-Performance-Assessment-Required wastes in Inventory Module 2 over Inventory Module 1 during 10,000 years and 1 million years following repository closure is 4 percent for all four waterborne chemical materials of concern (chromium, molybdenum, nickel, and vanadium).

8.3.1.3.3 *Atmospheric Radioactive Material Impacts*

There would be no incremental impact for airborne carbon-14 releases for Inventory Module 2. None of the additional waste packages would contain a waste form in which carbon-14 would exist in gaseous form (that is, as carbon dioxide). As for the Proposed Action and Inventory Module 1, radon-222 would be released as a gas but would decay to a solid isotope before escaping from the repository region (see Appendix I, Section I.7.3).

8.3.2 CUMULATIVE IMPACTS FROM OTHER FEDERAL, NON-FEDERAL, AND PRIVATE ACTIONS

This section discusses potential cumulative impacts from other Federal, non-Federal, and private actions that could contribute to doses at the locations considered in the performance assessment of the Yucca Mountain Repository. The actions identified with the potential for long-term cumulative impacts are past, present, and reasonably future actions at the Nevada Test Site and past actions at the low-level radioactive waste disposal facility near Beatty, Nevada.

8.3.2.1 Past, Present, and Reasonably Foreseeable Future Actions at the Nevada Test Site

Historically, the primary mission of the Nevada Test Site was to conduct nuclear weapons tests. Nuclear weapons testing and other activities have resulted in radioactive contamination and have the potential for radioactive and nonradioactive contamination of some areas of the Nevada Test Site. These areas and the associated contamination and the potential for contamination were evaluated for potential cumulative impacts with postclosure impacts from the proposed Yucca Mountain Repository. This section discusses these Nevada Test Site activities, the locations where these activities occurred, and the potential for cumulative long-term impacts with the repository.

Unless otherwise identified, DOE derived the information in this section from the Nevada Test Site Final EIS (DIRS 101811-DOE 1996, all). The Yucca Mountain site is in the southwestern portion of the Nevada Test Site along its western boundary, as shown in Figure 8-2.

At the Nevada Test Site, seven categories of activities have resulted in radioactive contamination or have the potential to result in radioactive and nonradioactive contamination:

1. *Atmospheric Weapons Testing.* One hundred atmospheric detonations occurred before the signing of the Limited Test Ban Treaty in August 1963. Atmospheric tests included detonations at ground level, from towers or balloons, or from airdrops.

2. *Underground Nuclear Testing.* Approximately 800 underground nuclear tests have occurred at the Nevada Test Site. Chapter 3, Figure 3-2 shows the locations of these tests in relation to Yucca Mountain. They included deep underground tests to study weapons effects, designs, safety, and reliability, and shallow underground tests to study the peaceful application of nuclear devices for cratering.

3. *Safety Tests.* Between 1954 and 1963, 16 above-ground tests studied the vulnerability of weapons designs to possible accident scenarios.

4. *Nuclear Rocket Development Station.* Twenty-six experimental tests of reactors, nuclear engines, ramjets, and nuclear furnaces occurred between 1959 and 1973. Figure 8-3 shows the location of the Nuclear Rocket Development Station.

5. *Shallow Land Radioactive Waste Disposal.* DOE disposed of some radioactive waste generated during testing in shallow cells, pits, and trenches. Because of the significant thickness of alluvial material and high mean annual temperatures and low precipitation under the current climate regime, downward advection of groundwater to the water table is highly unlikely. Therefore, shallow burial continues to be an important waste disposal activity at the Nevada Test Site (DIRS 155159-REECo, 1994, all; DIRS 108774-Tyler et al. 1996, all).

Section 8.3.2.1.3 discusses present and potential future low-level radioactive waste disposal activities.

6. *Crater Disposal.* DOE disposed of contaminated soils and equipment collected during the decontamination of atmospheric testing areas and the consolidation of radioactively contaminated structures, and other bulk wastes, in subsidence craters at Yucca Flat in Area 3. Figure 8-3 shows the location of Area 3 on the Nevada Test Site.

7. *Greater Confinement Disposal.* In 1981, Greater Confinement Disposal began at Area 5 for low-level radioactive wastes not suitable for shallow land disposal. This waste includes some transuranic radionuclides. Figure 8-3 shows the location of Area 5 on the Nevada Test Site.

Table 8-53 lists the approximate inventory for each of these categories. Atmospheric testing, shallow underground testing, safety testing, and nuclear rocket development all resulted in a small (less-than-40-curie) source term, which would not contribute substantially to cumulative impacts. Additionally, the inventories represented by crater disposal and shallow-land disposal were determined to not be important to cumulative impact considerations. Only the deep underground testing and greater confinement

Table 8-53. Summary of radioactivity on the Nevada Test Site (January 1996).[a]

Source	Area	Environmental media	Major known isotopes or wastes	Depth range	Approximate inventory (curies)
Atmospheric weapons testing	Aboveground nuclear weapon proving area	Surficial soils and test structures	Americium, cesium, cobalt, plutonium, europium, strontium	At land surface	20
Underground testing: shallow underground tests	Underground nuclear testing areas	Soils and alluvium	Americium, cesium, cobalt, europium, plutonium, strontium	Less than 61 meters[b]	1 at land surface; unknown at depth
Underground testing: deep underground tests	Underground nuclear testing areas	Soils, alluvium, and consolidated rock	Tritium, fission, and activation products	Typically less than 640 meters, but might be deeper	130 million[c]
Safety tests	Aboveground experimental areas	Surficial soils	Americium, cesium, cobalt, plutonium, strontium	Less than 0.9 meter	35
Nuclear rocket development area	Nuclear rocket motor, reactor, and furnace testing area	Surficial soils	Cesium, strontium	Less than 3 meters	1
Shallow land disposal	Waste disposal landfills	Soils and alluvium	Dry-packaged low-level and mixed wastes	Less than 9 meters	500,000[d,e]
Crater disposal	Test-induced subsidence crater with sidewalls, cover, and drainage	Soils and alluvium	Bulk contaminated soils and equipment	Less than 30 meters	1,250[d,f]
Greater confinement disposal	Monitored underground waste disposal	Soils and alluvium	Tritium, americium	37 meters	9.3 million[d,g]

a. Source: DIRS 101811-DOE (1996, p. 4-6). This table uses information and terminology from that document and is for information purposes only.
b. To convert meters to feet, multiply by 3.2808.
c. Source: DIRS 157116-Bowen et al. (2001, Table V, p. 21)
d. Inventory at time of disposal (not corrected for decay).
e. Inventory does not include prospective future low-level radioactive and mixed waste disposal (see Section 8.3.2.1.3).
f. Volume of waste considered for inventory was approximately 205,000 cubic meters (7.25 million cubic feet).
g. Volume of waste considered for inventory was approximately 300 cubic meters (10,000 cubic feet).

disposal categories represent substantial inventories that could, when combined with the repository inventory, potentially result in increased cumulative impacts.

8.3.2.1.1 *Underground Nuclear Testing*

The United States began a moratorium on the explosive testing of nuclear weapons in October 1992. As discussed in the Nevada Test Site EIS (DIRS 101811-DOE 1996), however, other weapons testing continues at the Test Site, including dynamic, hydrodynamic, and explosive tests. These tests are necessary for the continued assurance of the nuclear arsenal but do not result in nuclear explosions like those that were common during the Cold War. Environmental contamination is due largely to past weapons testing and not to the current limited activities at the Test Site. Although there are potential past and present impacts of the explosive testing of nuclear weapons, the long-lived radionuclides that such testing deposited far underground could pose future impacts, which this section evaluates.

As of September 23, 1992, the estimated total radionuclide source term for all tests was about 130 million curies (DIRS 157116-Bowen et al. 2001, Table V, p. 21). Because these radionuclides are either in or close to the water table and therefore subject to dissolution and possible transport by groundwater, they are referred to as the hydrologic source term. This source term represents the remaining radioisotopes (as of September 23, 1992) that could be available to the groundwater regime. However, because of the existence of multiple, complex migration pathways and limited characterization data, there is considerable uncertainty concerning the actual hydrologic source term. In recent years, the drilling of new characterization wells and the retrofitting of existing boreholes and wells have provided valuable new data that are now being integrated into the overall database so new evaluations can be made. These studies and planned future studies will help reduce the current levels of uncertainty concerning the quantity of radionuclides available for groundwater transport as well as uncertainty concerning both the mechanisms and consequences of radionuclide transport by groundwater flow at the Nevada Test Site. Testing with subcritical assemblies since 1994 has added quantities of material that are very small compared to the historical testing. Thus, the Department has based its analysis on the much larger inventory from historical testing (DIRS 156758-Crowe 2001, all).

There is recent evidence of plutonium migration from one underground test. Groundwater monitoring results indicate that plutonium has migrated about 1.3 kilometers (0.8 mile), possibly facilitated by the movement of very small and relatively mobile particles called *colloids* in the groundwater (DIRS 103282-Kersting et al. 1999, p. 59). No radioactive contamination attributable to underground tests has been detected in monitoring wells off the Nevada Test Site. DOE is conducting further monitoring and research to study these and other potential radionuclide migration phenomenon.

The above information indicates that groundwater could transport radionuclides from underground nuclear tests at the Nevada Test Site. This transport could result in releases from underground testing at the sites analyzed for releases from the proposed repository. DOE did not make long-term performance assessment calculations for the underground testing inventory with the same rigor as the analyses for the repository, and there is much uncertainty related to the hydrogeologic system. Since issuing the Draft EIS, DOE has continued to evaluate design features and operating modes that would reduce uncertainties in or improve long-term repository performance, including the waste package design, and improve operational safety and efficiency. The result of the design evolution process was the development of the Science and Engineering Report flexible design (DIRS 153849-DOE 2001, all). In addition, DOE has continued technical development of the Total System Performance Assessment since the publication of the Draft EIS, including further site characterization, improvements to the engineered system design, system performance assessment calculations, and quality assurance and validation of results. These efforts have resulted in an updated performance assessment referred to as the Total System Performance Assessment-Site Recommendation (TSPA-Site Recommendation; DIRS 153246-CRWMS M&O 2000). The results of this analysis for long-term impacts from the Yucca Mountain Repository are reported in Chapter 5 of this Final EIS. The TSPA-Site Recommendation evaluated the long-term performance of the Science and Engineering Report flexible design and included the best available information related to contaminant fate and transport. The results for the groundwater impacts from the repository in this analysis are substantially lower than reported in the Draft EIS. However, an update of this simplified scaling analysis used to estimate the potential cumulative impact from underground testing at the Nevada Test Site was not performed for the Final EIS because the principal factors affecting contaminant fate and transport remained essentially unchanged between the TSPA-Viability Assessment and the TSPA-Site Recommendation. DOE considers the estimates of Nevada Test Site groundwater impacts developed using the simplified model conservative and applicable for environmental evaluation. Further, any minor enhancements to these factors incorporated into the TSPA-Site Recommendation would have yielded results for an updated cumulative analysis well within the uncertainty reported for the analysis based on the TSPA-Viability Assessment. Therefore, DOE developed a simplified analysis that uses the TSPA-Viability Assessment (DIRS 101779-DOE 1998, all) repository infiltration and groundwater fate and transport models to scale groundwater impacts that could result from the underground test inventory. The analysis made the following assumptions for this calculation:

- The total 130-million-curie radionuclide inventory from underground testing at the Nevada Test Site would be available for transport. Tritium constitutes about 90 percent of the total underground testing inventory (DIRS 157116-Bowen et al. 2001, Table V, p. 21). However, the short half-life of tritium (about 12.5 years) would mean that radioactive decay would deplete the tritium inventory to insignificant levels in about 200 years, long before any Yucca Mountain releases would occur. Since potential impacts from tritium migration from the Test Site would not overlap repository impacts temporally, they would not be cumulative. Therefore, DOE did not consider them in this analysis.

- The radionuclide inventory available for transport at the repository would be the estimated curie content of the source material that would become wet in the 10,000-year analysis period. The analysis determined this amount by estimating the quantity of source material in the waste packages and cladding that are predicted to fail (*juvenile* and new *failures*) during the analysis period. Assuming that DOE would emplace 10,000 waste packages in the repository, the package failure rates developed in the TSPA-Viability Assessment indicate two waste package failures with 100 percent of contained elements exhibiting failed cladding. Since issuing the Draft EIS, DOE has continued to evaluate design features and operating modes that would reduce uncertainties in or improve long-term repository performance, including the waste package design, and improve operational safety and efficiency. The result of the design evolution process was the development of the Science and Engineering Report flexible design (DIRS 153849-DOE 2001, all). In addition, DOE has continued technical development of the Total System Performance Assessment since publication of the Draft EIS, including further site characterization, improvements to the engineered system design, system performance assessment calculations, and quality assurance and validation of results. These efforts have resulted in an updated performance assessment referred to as the Total System Performance Assessment-Site Recommendation [TSPA-Site Recommendation (DIRS 153246-CRWMS M&O 2000)]. The results of this analysis for long-term impacts from the Yucca Mountain Repository are reported in Chapter 5 of this Final EIS. The TSPA-Site Recommendation evaluated the long-term performance of the updated Science and Engineering Report flexible design and included the best available information related to contaminant fate and transport. The results for the groundwater impacts from the repository in this analysis are substantially lower than reported in the Draft EIS. However, an update of this simplified scaling analysis used to estimate the potential cumulative impact from underground testing at the Nevada Test Site was not performed for the Final EIS because the principal factors affecting contaminant fate and transport remained essentially unchanged between the TSPA-Viability Assessment and the TSPA-Site Recommendation. DOE considers the estimates of Nevada Test Site groundwater impacts developed using the simplified model conservative and applicable for environmental evaluation. Further, any minor enhancements to these factors incorporated into the TSPA-Site Recommendation would have yielded results for an updated cumulative analysis well within the uncertainty reported for the analysis based on the TSPA-Viability Assessment.

- The estimated total inventory for all underground tests at the Nevada Test Site was 130 million curies as of September 23, 1992 (DIRS 157116-Bowen et al. 2001, Table V, p. 21). As discussed above, the contribution to the total inventory from subcritical experiments is very small and is adequately accounted for by analyzing the inventory from historical testing (DIRS 156758-Crowe 2001, all). The Department only evaluated the radionuclides of interest (that is, those that result in 99 percent of the impact; technetium-99, iodine-129, and carbon-14) in this inventory (see Section 5.4.1 of the Draft EIS for details.)

- The total underground testing inventory available for transport would migrate through the same locations as those considered in this EIS for dose calculations for releases from the repository. This is very conservative because much of the water migrating from the underground test locations would discharge to locations other than those for releases from the proposed repository. Such locations include Oasis Valley, Ash Meadows, or the Amargosa Desert.

- The radionuclide-specific distribution coefficients, k_d, are assumed to be equal for source materials at the repository and the Nevada Test Site. This assumption recognizes that most of the nonvolatile radionuclide inventory at the Test Site is captured within the glass-like material resulting from the intense heat generated by past underground tests. The analysis assumed that the leachability of this material is not remarkably different than that of ceramic spent nuclear fuel pellets. Concentrations of the contaminants (curies per milliliter) in leachates are directly proportional to the source material (curies per gram) and the radionuclide-specific distribution coefficients.

- All contaminants originating on the Nevada Test Site would flow to the same discharge points as contaminants from Yucca Mountain, as modeled by the TSPA-Viability Assessment, and the peak groundwater concentrations of contaminants from the Test Site would coincide (in time and space) with the peak groundwater concentrations from repository contaminants.

- Concentrations of radionuclides in the groundwater would be diluted by total infiltration through the repository footprint and groundwater recharge for the repository and the Nevada Test Site, respectively.

The absolute potential cumulative Nevada Test Site groundwater impact can be estimated by comparison with the 10,000-year impacts presented in Table 5-4 of the Draft EIS. Based on these tables, the estimated cumulative Test Site impacts for the Proposed Action for the maximally exposed individual would be about 0.007 millirem per year at 20 kilometers. The dose to the RMEI at 18 kilometers, as described in Chapter 5, would be slightly higher. Therefore, the estimated total potential cumulative impact (Yucca Mountain impact plus Nevada Test Site impact) would be essentially (because of the small contribution from the proposed repository) 0.007 millirem per year to the RMEI.

Because of the large uncertainties in the current level of understanding of the hydrogeologic system, DOE has not attempted to model the actual groundwater transport of the Nevada Test Site with this simplified model. However, by assuming that the radionuclide contaminants in the groundwater at the Test Site would be transported in an identical manner to those from the repository and that peak concentrations would occur at precisely the same time, the Department believes that the resulting estimates of cumulative impacts from underground testing activities represent a reasonable upper bound of the actual cumulative impacts.

Uncertainties associated with Nevada Test Site groundwater impacts:

- *Source material concentration* – The concentration of contaminants within the source material is the parameter with the most sensitivity to outcome but also the parameter that the least is known about at the Nevada Test Site. However, the actual Test Site concentrations could be higher than those estimated for this analysis and still have little effect on the outcome. This is because, as the density of the Test Site inventory increases (that is, the radionuclide inventory is assumed to occupy a smaller volume), the quantity of infiltration "seen" by the contaminant would decrease because of the reduced footprint of the source term. Since both of these terms (radionuclide density and water infiltration per unit area) are directly proportional to the calculated groundwater concentration, they would tend to offset one another. However, for conservatism, the assumption was made that all of the Test Site source term for radionuclides of interest was concentrated only in the affected soil at Yucca Flat. This assumption could have resulted in an overestimate of the Test Site concentration and potential impacts by as much as two.

- *Travel distances and times* – The conservative assumption was made that the contaminants from Yucca Mountain and the Nevada Test Site would travel along the same pathways (those assumed for Yucca Mountain in the TSPA-Viability Assessment) and at the same time to maximize potential impacts. If more realistic modeling had been performed, the peak contaminate concentrations from Yucca Mountain and the Test Site probably would not coincide and the Test Site contribution to the cumulative impacts would therefore be smaller than those estimated.

- *Solute partition coefficients* – These coefficients as described in the literature are known to vary by orders of magnitude depending on soil and source zone material types. Because the precise nature of the soils at the Nevada Test Site was not considered in the simplified analysis, the actual result could be different. However, these values are not readily available and are impossible to estimate accurately with currently available data.

- *Contaminant mobilization* – To simplify the analysis, the assumption was made that the waste isolated in engineered barrier systems for the Yucca Mountain Repository and the waste dispersed in glass-like material from underground nuclear blasts at the Nevada Test Site will have the same release characteristics. The actual mechanisms for waste mobilization for Test Site underground testing contamination are largely unknown. The actual differences in the mobilization of the contaminants could result in changes (larger or smaller) in the impact estimates, however, due to the relative size of the calculated impacts, coupled with the other conservatisms assumed in this simplified analysis, they are not likely to influence the conclusion.

- *Groundwater flow direction and discharge points* – If realistic modeling was performed, and adequate characterization data to support that modeling was available, then it is extremely unlikely that the modeling would show that all contaminants resulting from underground testing across the Nevada Test Site would migrate to only one discharge point and that point would be the same point of discharge as the releases from the Yucca Mountain Repository. More detailed information on actual groundwater flow would likely serve to reduce the estimated impact of the Test Site inventory.

8.3.2.1.2 *Greater Confinement Disposal*

Waste disposed of at the Nevada Test Site under Greater Confinement Disposal constitutes a radiological source term that is less than 10 percent of the repository radionuclide source term immediately available for groundwater transport when the first waste packages at the Yucca Mountain Repository are assumed to have initially degraded (that is, 2 percent of the total repository radionuclide source term). The waste disposed of by Greater Confinement Disposal was placed in boreholes that are approximately 37 meters (120 feet) deep; the waste itself is no closer than approximately 21 meters (70 feet) to the surface. DOE has reviewed analyses related to the Nevada Test Site and has concluded that there is no credible pathway for long-term releases of materials by resuspension of nonvolatile radionuclides because the material is sufficiently far below the surface. In addition, evapotranspiration exceeds precipitation in this region, which, coupled with the fact that the boreholes are sufficiently above the water table (more than 125 meters), indicates that there is no credible release scenario for Greater Confinement Disposal material to enter the groundwater. Therefore, DOE expects no cumulative impacts from Greater Confinement Disposal activities.

8.3.2.1.3 *Future Nevada Test Site Low-Level Waste Disposal*

The Nevada Test Site is a disposal site for low-level radioactive waste generated by DOE-approved generators. Managed radioactive waste disposal operations began in the early 1960s, and DOE has disposed of low-level, transuranic, mixed, and classified low-level wastes in selected pits, trenches, landfills, and boreholes on the Nevada Test Site. Environmental impacts from the disposal of low-level waste at the Nevada Test Site are discussed in the Nevada Test Site Final EIS (DIRS 101811-DOE 1996, pp. 2-15 to 2-17). The current source term of low-level and mixed wastes in shallow land disposal on the Nevada Test Site does not constitute a substantial inventory in relation to the radionuclide source term immediately available for groundwater transport from the repository when the first waste packages initially degrade (that is, 2 percent of the total repository radionuclide source term). However, shallow burial of low-level radioactive waste continues to be an important waste disposal activity at the Nevada Test Site. Therefore, this section evaluates reasonably foreseeable future activities in this category as a potential cumulative impact.

Waste disposal activities on the Nevada Test Site occur at two specific locations. They are the Area 3 and Area 5 Radioactive Waste Management Sites. The Area 3 Radioactive Waste Management Site is on Yucca Flat and covers an area of approximately 0.2 square kilometer (50 acres). DOE uses conventional landfill techniques to dispose of contaminated debris from the Nevada Test Site Atmospheric Testing Debris Disposal Program and packaged bulk low-level waste from other DOE sites in subsidence craters from underground nuclear tests. The estimated total remaining capacity for low-level waste in the Area 3 site is 1.8 million cubic meters (64 million cubic feet) (DIRS 103224-DOE 1998, Section A.5.2) .

DOE has used the Area 5 Radioactive Waste Management Site since 1961 to dispose of low-level waste and classified low-level waste from Nevada Test Site operations. In 1978, the Test Site began accepting low-level waste generated by other DOE sites. The total area of the Area 5 site is 3 square kilometers (740 acres). The developed portion occupies 0.37 square kilometer (92 acres) in the southeast corner and contains 17 landfill cells (pits and trenches), 13 Greater Confinement Disposal boreholes, and a transuranic waste storage pad. DOE is seeking a Resource Conservation and Recovery Act permit for Pit 3 as a mixed-waste disposal unit. In the future, if the mixed-waste volume warranted it, the Department might consider obtaining a new unit and, hence, a new permitted facility. However, current projected waste volumes do not indicate the need for an additional mixed-waste disposal unit at this time. The estimated total remaining capacity for low-level waste in the Area 5 Radioactive Waste Management Site is 1.2 million cubic meters (42 million cubic feet) (DIRS 103224-DOE 1998, Section A.5.3).

As discussed in Section 8.2.12.1, DOE projects a need for 1.1 million cubic meters of capacity for low-level waste disposal at the Nevada Test Site through 2070 (DIRS 155856-DOE 2000, Table 4-1).

The Final Waste Management Programmatic EIS (DIRS 101816-DOE 1997, Summary) reported volumes of radioactive waste DOE may dispose of at the Nevada Test Site for "current plus 20 years" of waste disposal. The current inventory plus 20 years of additional disposal inventory would total 3,000 cubic meters (106,000 cubic feet) of low-level mixed waste, 1,700 cubic meters (60,000 cubic feet) of low-level waste, and 610 cubic meters (21,500 cubic feet) of transuranic waste (DIRS 101816-DOE 1997, Summary, p. 102). The Nevada Test Site Final EIS (DIRS 101811-DOE 1996, Table 4-1, p. 4-6) estimates the total current inventory already in shallow disposal at the Nevada Test Site to be 500,000 curies at the time of disposal (uncorrected for decay to the present time).

According to the Final Waste Management Programmatic EIS, the only expected groundwater impacts from low-level mixed, low-level radioactive, and transuranic waste disposal at the Nevada Test Site in excess of regulatory limits are for the hazardous chemicals 1,2-dichloroethane, methylene chloride, and benzene, and those only under Regionalized Alternative 3 and the Preferred Alternative in that EIS (DIRS 101816-DOE 1997, p. 11-61). None of these hazardous chemicals would be in the Yucca Mountain

Repository inventory, so there would be no potential cumulative impacts from those chemicals from the Proposed Action or Inventory Module 1 or 2.

DOE has estimated potential long-term impacts from radioactive material disposed of at the Nevada Test Site. DOE based its calculations of long-term atmospheric releases for the Nevada Test Site on estimates of the inventory at the Test Site that could be accessible by residents around the area. For this calculation, the Department considered three potential sources of radionuclide releases:

- The Area 3 radioactive waste disposal area
- The Area 5 radioactive waste disposal area
- Soil sites around the Nevada Test Site that are contaminated at or near the surface from nuclear weapons testing

Because this material is not near the water table and because evapotranspiration exceeds precipitation in this area, there is no credible release scenario for this material to enter the groundwater. DOE postulated that, over time, weathering at the site could resuspend contaminants in the air and transport them from the contaminated areas to offsite residents. Therefore, DOE performed calculations using current meteorological information for the Nevada Test Site and site-specific resuspension factors to estimate the amount of material that could be released off the site. To ensure conservatism in the estimate, DOE assumed that the three sources listed above were in the same location (even though in reality they are separated by large distances) and that a future resident could be as near as 100 meters (330 feet) from the site. Analyses based on these assumptions are likely to overestimate the true impacts to a future resident because they result in a calculated total emission and radiation dose that is probably higher than if a resident were within 100 meters of a single site.

Based on these conservative assumptions, DOE calculated that the total radiation dose from the three sources could be approximately 7 millirem for each year of exposure during the first 10,000 years, and DOE does not expect that the dose would increase beyond that value for as long as 1,000,000 years. If a resident received this dose as long as 70 years, that person's lifetime dose could be as high as 490 millirem, which could result in an increased risk of fatal cancer of 0.0002.

8.3.2.2 Past Actions and Present Actions at the Beatty Low-Level Radioactive Waste Disposal and Hazardous Waste Treatment Storage and Disposal Facilities

A low-level radioactive waste disposal facility, formerly operated by U.S. Ecology, a subsidiary of American Ecology, is 16 kilometers (10 miles) southeast of Beatty, Nevada, and 180 kilometers (110 miles) northwest of Las Vegas. This site is about 15 kilometers (9.3 miles) west of the proposed Yucca Mountain Repository (see Figure 8-2). The disposal facility, which opened in 1962, covers roughly 0.14 square kilometer (35 acres) of unlined trenches. Acceptance of low-level radioactive waste ended December 31, 1992 (DIRS 101815-DOE 1997, Chapter 4, Table 4-17). The Nevada State Health Division formally accepted permanent custody of the low-level radioactive commercial waste disposal in a letter to American Ecology dated December 30, 1997 (DIRS 148088-AEC 1998, all). An adjacent U.S. Ecology facility remains open for hazardous waste disposal.

From 1962 through 1992, the inventory shipped to the Beatty low-level radioactive waste facility totaled 137,000 cubic meters (4.8 million cubic feet) in volume (DIRS 101815-DOE 1997, Chapter 4, Table 4-17) with radioactivity of about 640,000 curies (DIRS 101815-DOE 1997, Chapter 4, Table 4-18). The radioactivity in this sum was measured by year of shipment (that is, it is not corrected for decay since that time).

The Manifest Information Management System (DIRS 148160-MIMS 1992, all) calculated the total radionuclide inventory the Beatty facility received from 1986 through 1992, which represents 29 percent of the total undecayed inventory at that facility. Even if multiplied by a factor of 3 to 4 to compensate for the period (1962 to 1985) for which the Manifest Information Management System did not provide information, the source term represents a small percentage of the radionuclide source term immediately available for groundwater transport from the repository when the first waste packages initially degrade (that is, 2 percent of the total repository radionuclide source term). Therefore, cumulative long-term impacts from the Beatty Low-Level Radioactive Waste Disposal Facility with the repository would be very small.

The U.S. Ecology Hazardous Waste Treatment, Storage and Disposal Facility is a Resource Conservation and Recovery Act-permitted facility, with engineered barriers and systems and administrative controls that minimize the potential for offsite migration of hazardous constituents.

8.4 Cumulative Transportation Impacts

This section discusses the results of the cumulative impact analysis of transportation. Paralleling the transportation analyses of the Proposed Action in Chapter 6, potential national transportation cumulative impacts from Inventory Module 1 or 2, and past, present, and reasonably foreseeable future actions, are presented in Section 8.4.1. Potential cumulative impacts with construction and operation of the Nevada transportation implementing rail and heavy-haul truck alternatives are included in Section 8.4.2.

The shipment of Inventory Module 1 or 2 to the repository would use the same transportation routes, but would take more shipments and an additional 14 years compared to the Proposed Action. Table 8-2 lists the estimated number of shipments for Modules 1 and 2. Impacts from Module 1 or 2 would be similar because the shipping rate would be the same for spent nuclear fuel and high-level radioactive waste and only about 3 percent more shipments would be made over the 38-year period under Module 2 to transport Greater-Than-Class-C and Special-Performance-Assessment-Required wastes. Because the difference in impacts between Inventory Modules 1 and 2 would be small, the following discussions present the impacts from both modules as being the same.

8.4.1 NATIONAL TRANSPORTATION

This section describes cumulative impacts from national transportation. Section 8.4.1.1 presents potential cumulative impacts from shipping Inventory Module 1 or 2 from commercial nuclear generating sites and DOE facilities to the proposed Yucca Mountain Repository (Section 8.4.1.1). Section 8.4.1.2 presents potential cumulative national transportation impacts for the Proposed Action and Module 1 or 2 when combined with past, present, and reasonably foreseeable future shipments of radioactive material.

8.4.1.1 Inventory Module 1 or 2 Impacts

This section describes the potential cumulative impacts of loading operations at generating sites and incident-free radiological impacts, vehicle emission impacts, and accident impacts associated with transportation activities for Inventory Module 1 or 2. Cumulative impact results are provided for the mostly legal-weight truck and mostly rail scenarios which are described in Chapter 6. The section also describes potential cumulative impacts from transportation of other materials, personnel, and repository-generated waste for Modules 1 or 2. Appendix J contains additional detailed analysis results.

Loading operations would be extended for an additional 14 years to load the greater quantities of spent nuclear fuel and high-level radioactive waste under Inventory Module 1 or 2. The impacts of routine loading operations described for the Proposed Action in Chapter 6, Section 6.2.2, would increase for Module 1 or 2 due to the additional inventory. Therefore, the increase in dose to the public would be